Status of the Science

On Questions that Relate to BLM Plan Amendment Decisions and Peninsular Ranges Bighorn Sheep
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Table of Contents

A. Causal Links Between Mortality, Fecundity, Survival and Land Uses

The cause and effect relationships between human disturbance and bighorn sheep populations are not well understood. General information and systematic research studies are lacking. Most studies have focused on one aspect of disturbance (generally sheep responses to human encounters) while few have clear ties to population level effects, known levels of human use, or historic factors influencing response of bighorn sheep to disturbance (King and Workman 1986).

Factors suggested as contributors to bighorn population declines includes roads, trails, housing developments, and fire suppression (Etchberger et al. 1989, Krausman et al. 2000, Kelly and Krausman et al. 2000). Some of the evidence appears to conflict (Kelly and Krausman 2000). Between 1991 and 1996, 34% of adult bighorn mortalities in the northern Santa Rosa Mountains were directly attributed to the effects of urbanization. Five sheep were killed by automobiles, 5 by eating toxic plants, and 1 by strangulation in a wire fence (Bighorn Institute 1997). Conversely, lamb productivity at a construction site in Nevada did not depart from the average productivity measured since 1969 (Leslie and Douglas 1980). The authors were concerned however that recruitment may have been affected (Leslie and Douglas 1980). In addition, the same study did find that 9 of 17 marked ewes abandoned historical watering sites for alternate sites in apparent response to construction activity (Leslie and Douglas 1980).

The present population size of peninsular bighorn sheep argues for action, in combination with further study, to ensure recovery. Given the current level of knowledge and publicly-available data, the potential for population effects resulting from management actions will largely be inferential based on judgments made from literature and data on the indirect effects of human activities on bighorn sheep populations.

The following literature review summarizes some of the more important literature on the impacts to bighorn sheep.

B. Disturbance Response of Bighorn Sheep

1. Generalized sheep response to human disturbance

Many authors have found that human disturbance can alter habitat use and activity patterns of bighorn sheep (e.g., Van Dyke et al. 1983, Miller and Smith 1985, King and Workman 1986, Etchberger et al. 1989, Papouchis et al. 2000). Population declines (Van Dyke et al. 1983, Etchberger et al. 1989, Harris 1992), shifts in habitat use (Van Dyke et al. 1983), interruption of seasonal migration routes (Ough and deVos 1984), has been linked to human disturbance. Disturbance is often tied to recreation use and urban interface issues. Timing and location of recreation in bighorn habitat, the distance between sheep and humans, and the presence of domestic dogs has a role in the impact of human activities on bighorn sheep.

2. Generalized response of bighorn to recreation use

Many researchers have illustrated that sheep exhibit a response to recreational activities. MacArthur et al. (1979 and 1982) found that bighorn sheep exhibited elevated heart rates in response to the presence of people, especially when people were approaching with a dog or from over a ridge. Miller and Smith (1985) found that bighorn had a stronger adverse reaction to 1 or 2 humans on the ground than to parked vehicles or a light airplane circling overhead. Papouchis et al. (2000) found that bighorn sheep had a greater flight response to hikers than to mountain bikers or cars. King and Workman (1986) noted that responses may be more severe in areas where animals have historically been exposed to relatively high levels of human activity. In addition, the history of hunting bighorn sheep may be an important variable to consider when evaluating the impacts of human disturbance in bighorn habitat (King and Workman 1986, see also Hansen

1970, Geist 1971, Horesji 1976). Krausman et al. (2000) postulate that human recreation was a contributing factor in the decline of bighorn sheep in three southwest populations. However, not all researchers agree that recreation has a detrimental effect on bighorn sheep. Hamilton et al. (1982) found that there was no difference in levels of sheep disturbance when heavy use recreation areas were compared to light use recreation areas in the San Gabriel Mountains of California. However, they also noted that sheep avoided using a salt lick while humans were in the vicinity. Hicks and Elder (1979) found that recreation users had no negative effect on bighorn sheep in the Sierra Nevada; however, they cautioned land managers to monitor the amount of recreation and to instigate or continue to regulate recreation use in bighorn habitat.

3. Effects of Recreation Use Relative to Season

Timing of recreation use relative to the life cycle of bighorn sheep is important. Impacts to ewes that are pregnant or lactating can have the most deleterious effects (Geist 1971, Light and Weaver 1973, King and Workman 1986, Wagner and Peek 1999). Flight responses can be very severe when ewes are with young lambs. King and Workman (1986) and Wehausen (1980) documented a heightened awareness to human activity when lambs were present. Ewes with lambs tend to remain close to dependable water sources (Leslie and Douglas 1980, McCarty and Bailey 1994) with density and proximity to water increasing during the summer months (BLM 1980, Blong and Pollard 1968). Travel corridors between lambing areas and watering areas are also important and disruption could impede access to important resources (Ough and deVos 1984, Van Dyke et al. 1983).

4. Effect of Position of Disturbance Relative to Reaction of Bighorn

Research has shown that bighorn sheep exhibit a stronger, adverse reaction to humans approaching from above them than humans approaching from below (MacArthur et al. 1982, Hicks and Elder 1976, Geist 1971). Approaching from over a ridge may limit escape options for bighorn sheep. MacArthur et al. (1982) found that sheep withdrew when a human was approaching from over a ridge (> 50 meters away) 27.6% of the time but withdrew only 3.6 % of the time when approached from a road not above the bighorn.

5. Bighorn Response Relative to Distance at Encounter

Response based on distance between the bighorn and the source of disturbance has been generally documented. Both flight and cardiac responses seem to be stimulated between about 50 and 100 meters (Holl and Bleich 1983, MacArthur et al. 1982, Miller and Smith 1985). The exception is helicopter disturbance where the distance is above 400 meters (Bleich et al. 1994). The distance at which sheep become aware of the disturbance can also affect how far they move away from the disturbance (Miller and Smith 1985). Distance alone is a poor predictor of behavioral response to disturbance. Responses are variable and group size and gender compositions are also important factors (Miller and Smith 1985).

6. Bighorn Response to Domestic Dogs

Bighorn sheep evolved with canine predators (Geist 1971) and thus react very strongly to domestic dogs. Disturbance of bighorn by dogs causes heart rate increases and flight response (MacAruthur et al. 1979, MacArthur et al. 1982, Purdy and Shaw 1981). Sheep will remain nervous and alert for up to 30 minutes following a dog encounter, responding to subtle stimuli with otherwise evoked no response (MacArthur et al. 1982). Goodson et al. (1999) noted that the elimination of camping and dogs in important sheep habitat resulted in a reduction in the effects of human disturbance to bighorn.

7. Bighorn Response to Hiking

Researchers have shown that bighorn sheep exhibit a response to hikers (e.g., Hicks and Elder 1979, Miller and Smith 1985, Papouchis et al. 2000). Miller and Smith (1985) found that sheep had a strong reaction (immediate flight response) to the presence of 1 or 2 humans on foot (38% and 49% of the total responses respectively). MacArthur et al. (1982) also found that sheep had a strong behavioral and cardiac response when approached from over a ridge by a human or a human with a dog. In addition, Hamilton et al. (1982) found that sheep avoided using areas while humans were present but were not permanently displaced by hikers. Bighorn behavior was modified to avoid human interactions at salt licks or waterholes, visiting each earlier or later in the day when humans were not present (Campbell and Remington 1981, Hamilton et al. 1982). The level of response seems to be affected by a number of factors such as direction of approach (I.e., from above, across a ridge, below, or level) or the presence or absence of a dog (MacArthur et al. 1982), levels of previous disturbance and the history of hunting (King and Workman 1986), composition of the bighorn group (i.e., presence of ewes with lambs) (Wehausen 1980, Miller and Smith 1985, King and Workman 1986), and the size of the group of sheep (Berger 1978, Miller and Smith 1985). Papouchis (2000) found a more frequent flight response from hiking disturbance than from mountain biking or vehicles. Conversely, Hamilton et al. (1982) did not detect any significant difference in bighorn distribution between heavily-used and lightly-used recreation areas. Hicks and Elder (1976) concluded that foot trails did not affect sheep movement on summer range in the Sierra Nevada mountains. To date, research has not established a link between hiking and population level effects on bighorn sheep.

Studies indicate that roads adversely impact bighorn sheep by inducing flight, causing mortality, elevating heart rate, and fragmenting habitat by cutting off traditional movement corridors. Roads impede movement between habitat patches (Cunningham 1982, Ough and deVos 1984). Back country roads that receive low use may have little or no effect on bighorn sheep, but other roads have caused bighorn to alter traditional migration routes (Van Dyke et al.1983, Ough and deVos 1984). Stress responses can occur and flight responses are possible. MacArthur et al. (1982) found that 8.8% of vehicle passes in sheep habitat elicited an increase in heart rate, which the authors interpreted as a stress response. In addition, they found that flight responses were induced in only 0.9% of those vehicle passes (MacArthur et al. 1982). Papouchis et al. (2000) reported that the average distance maintained from a road increased along heavily used roads that went through remote areas. Human use of a road along or through lambing, bedding, or watering areas eliminates the solitude and security for bighorn (Van Dyke et al. 1983, Jorgensen 1974). Cunningham and deVos (1992) found that ewes with home ranges bisected by a state highway had a 24% probability of being killed while crossing the highway. MacArthur (1979) found that ewe heart rates increased decreased as distance from roads increased and that at less than 200 meters from the road heart rates were elevated above average.

9. Response of Bighorn to Human Disturbance at Watering Areas

Bighorn sheep typically range within 2 miles of free water (Geist 1971, Van Dyke et al. 1983) and are highly dependent upon reliable water sources especially during the hot season (BLM 1980). Bighorn activity has been found to decrease on days when vehicle use interrupts access to water (Jorgensen 1974). Constant or frequent human use (e.g., cross country travel, camping, off-road vehicles) at or near water sources, particularly during the summer months, may adversely affect sheep and may cause them to abandon the water source in favor of less disturbed areas (Blong 1967, DeForge 1972, Cunningham 1982, Miller and Smith 1985). Leslie and Douglas (1980) recorded alterations in behavior and movement coincident with construction activity near a sheep water source.

10. Bighorn Response to Cattle Grazing

"Cattle grazing can be detrimental to bighorn sheep populations, either through direct competition for forage or water, or through vegetation changes in response to cattle grazing" (reviewed by McQuivey 1978 and Jones 1980 *in* USFWS 2000). In addition, Goodson et al. (1999) found that bighorn sheep used areas less after intensive cattle grazing.

11. Bighorn Response to Wild Horses

Competition between feral horses and bighorn sheep has not been extensively studied. However, increasing horse populations were reported to coincide with decreasing bighorn Populations in the Silver Peak Range of Nevada (McQuivey 1978). Coates and Schemitz (1994 *in* USFWS 2000) suggested that association with feral horse herds may result in increased foraging efficiency for bighorn rams because rams may spend less time watching for predators and more time foraging. However, the overall fitness of these rams was not examined. Goodson et al. (1999) noted an increase in sheep use of an area after the feral horse herd was reduced.

12. Bighorn Response to Helicopters

"Helicopter surveys may adversely affect populations of mountain sheep…by altering the movement, habitat use, and foraging efficiency of sheep so that survivorship or reproduction is reduced" (Stockwell 1991 *in* Bleich et al. 1994). Bighorn can respond so dramatically to helicopter use that it may override other factors affecting sheep movement (Bleich et al. 1990, Bleich et al. 1994). Sheep do not habituate or become sensitized to repeated helicopter flights (Bleich et al. 1994). MacArthur et al. (1982) reported no heart rate responses in bighorn sheep to helicopters above 400 meters in altitude. Helicopter flights at 90-250 meters above the ground increased the heart rate in ewes 2.5 - 3 times above normal. Bleich et al. (1994) found that radio collared bighorn moved significantly farther following a helicopter survey than on the day prior to a survey. Helicopter overflights may also reduce foraging efficiency during winter (Harris 1992). Miller and Smith (1985) recommended that helicopter flights be kept at over 100 meters above ground level to minimze impacts to bighorn sheep.

C. Habitat and Population Management Concerns and Issues

1. Loss of Connectivity:

Anecdotal and genetic evidence suggests potential for historic connections between peninsular bighorn sheep and bighorn to the north (Boyce et al. 1997, Guitierrez-Espleleta et al. 1998, Boyce et al. 1999). Urban development along the floor of the Coachella Valley, Highways 111 and 74, and Interstates 10 and 8, may prevent movement of sheep and reduce genetic mixing which otherwise may have occurred when bighorn crossed the desert flats between ranges (Leslie and Douglas 1980, Bleich et al. 1990, Bleich et al. 1996,). This lack of connectivity and genetic exchange may have long term implications for both persistence, recolonization, and the maintenance of fitness and population viability (Berger 1990).

2. Response to Artificial Water Sources:

It has been suggested that water is a major limiting factor to abundance of peninsular bighorn sheep in the Santa Rosa Mountains (Blong 1967, BLM 1980). Bighorn abandoned the Magnesia Spring water source as development encroached and began using a new water source in nearby Bradley Canyon (Blong 1967). It has been suggested that bighorn sheep summer use areas could be extended by providing artificial water sources in portions of the range lacking reliable water sources (Blong 1967, Leslie and Douglas 1980, BLM 1980).

3. Potential Effects of Fire Suppression:

Bighorn sheep rely on keen vision to detect predators (Geist 1971, Wakelyn 1987, Risenhoover Bailey (1985) and avoid areas of dense vegetation that obscure visibility (Geist 1971, McCann 1956, Oldemeyer et al. 1971, Risenhoover and Bailey 1980). Wakelyn (1987) and Risenhoover and Bailey (1985) found that foraging efficiency was reduced in bighorn sheep foraging in dense cover. It has been suggested that visual obscurity has a measurable impact on habitat use and range expansion by bighorn sheep (Ough and deVos 1984, Risenhoover and Bailey 1985, Fairbanks, et al. 1987, Wakelyn 1987). Fire suppression has been identified as a major cause of change in vegetation density in the western United States (Miller and Wigand 1994, Miller 1999) and has been causally related to habitat avoidance and abandonment by bighorn sheep (Shannon et al. 1978, Risenhoover and Bailey 1985, Etchberger et al. 1989, Bleich et al. 1997, Andrew 1994).

D. Study Area Characteristics:

Each research study included in this literature review has a unique design and study area. These unique characteristics increase the difficulty in isolating causal factor which represent the relationship between observed population trends and the nature and amount of disturbance. Variables assessed include the amount of habitat available to the bighorn, herd size (Van Dyke et al. 1983, Berger 1990, Harris 1992), connectivity to other population groups (Leslie and Douglas 1980) and differences in the type or amount of human use. The synopses provided below are taken from a few of the studies cited in this review to provide a contextual framework.

Krausman, P. R., W. C. Dunn, L. K. Harris, W. W. Shaw, and W. M. Boyce. 2000. Can mountain sheep and humans coexist? In prep. 10pp.

> This paper reviews population declines in bighorn sheep in three areas in the southwest: the Sandia Mountains, New Mexico, the Santa Catalina Mountains, Arizona, and the Northern Santa Rosa Mountains, California. Similarities exist among the study areas, including similar vegetation associations, steep slopes and cliffs, canyons, and washes which characterize bighorn habitat in each range. Each of the areas assessed are adjacent to human habitation. The Sandia Mountains are near Albuquerque, NM, the Santa Catalina mountains are adjacent to Tucson, AZ and include the Pusch Ridge Wilderness, and the Santa Rosa mountains are adjacent to Palm Springs, CA. Human disturbance was examined using human population growth and recreation in sheep habitat as an index to disturbance. Differences among these populations include the subspecies of bighorn sheep present (Sandia Mountains - Rocky Mountain bighorn sheep), native vs. introduced population (Sandia Mountains bighorn introduced in 1939 and 1941), and amount of bighorn habitat identified (Sandia Mountains 40 km^2, Santa Catalina mountains 20 km^2, Northern Santa Rosa Mountains not available).

Hamilton, K., Holl, S. A., and Douglas, C. L. 1982. An evaluation of the effects of recreational activity on bighorn sheep in the San Gabriel mountains, California. Desert Bighorn Council Transactions. 26: 50-55.

> This study examined the effects of recreation activities on bighorn sheep in the San Gabriel mountains of southern California. Two trails crossing summer bighorn sheep range were used to assess whether high numbers of hikers were influencing habitat use by bighorn sheep. Trail use by hikers was monitored in August 1980 and June through September 1991 using time lapse cameras, direct observation, and trail registers.

MacArthur, R. A., V. Geist, R. H. Johnston. 1982. Cardiac and behavioral responses of mountain sheep to human disturbance. Journal of Wildlife Management 46: 351-358.

This study was conducted at the Sheep River Wildlife Sanctuary in Alberta, Canada. There is a gravel road that runs through the Sheep River valley and bighorn sheep may be exposed to 25-30 vehicles per hour during peak recreational use. The authors implanted heart monitors in 8 bighorn sheep to assess physiological effects of human disturbance on bighorn sheep. Disturbance was induced by researchers walking toward the sheep from a vehicle, sitting in a parked vehicle, or approaching with a dog on a leash.

Papouchis, C.M., F. J. Singer, W. Sloan. 2000. Effects of increasing recreational activity on desert bighorn sheep in Canyonlands National Park, Utah. In press.

Situated in a remote area of Canyonlands National Park, Utah, this study assessed the impacts of recreation activities on desert bighorn sheep. Behavioral responses of bighorn sheep to hikers, mountain bikers, and vehicles were recorded to address two contradictory hypotheses: 1) bighorn sheep will avoid or abandon habitat when humans are present, 2) bighorn sheep will habituate to predictable human activities or may compensate by using alternate habitat away from the disturbance. Field assistants initiated 98% of the hiking disturbance trials, 24% in high-use areas and 77% in low-use areas. Recreational use was disproportionate across the types of use, hikers (9%), mountain bikers (67%), and vehicles (24%).

Purdy, K. G. and W. W. Shaw. 1981. An analysis of recreational use patterns in desert bighorn habitat: the Pusch Ridge Wilderness case. Desert Bighorn Council Transactions 25: 1-5.

The Pusch Ridge Wilderness is located near Tucson, Arizona and in 1980 received approximately 34,000 visitors. Photoelectric trail traffic counters, unmanned registration stations, voluntary survey forms, telephone surveys, and direct observations were used to assess recreation use patterns and the response of bighorn sheep to human disturbance.

Disclaimer: Caution should be exercised when making inference from case studies to other sites or situations. Circumstances are rarely identical and often are very different. For example, the Pusch Ridge Wilderness receives more than 1,000,000 visitors use days per year and is surrounded by urban development, whereas in the San Jacinto and Santa Rosa Mountains urban encroachment is confined to the north side of the range west of Thermal and visitor use levels are much lower. In Canyonlands National Park hiking is a less common form of recreation than it is in the San Jacinto and Santa Rosa mountains. Urban encroachment was not a factor in the Hicks and Elder study from 1976 whereas in the San Jacinto and Santa Rosa mountains urbanization plays a major role. In the San Gabriel mountains, the large urban expanse of Los Angeles does not encroach directly on sheep habitat, but the large L.A. population supplies many visitors to the mountains. Differences exist between most of the case studies cited in this review. Caution should be used when comparing these case studies to bighorn sheep and human interactions in the Peninsular Ranges.

Literature Cited

Andrew, N. G. 1994. Demography and habitat use of desert-dwelling mountain sheep in the east Chocolate Mountains, Imperial County, California. MS thesis. University of Rhode Island. 135pp.

Berger, J. 1978. Group size, foraging, and antipredator ploys: an analysis of bighorn sheep decisions. Behavioral Ecology and Sociobiology 4: 91-99.

Berger, J. 1990. Persistence of different sized populations: an empirical assessment of rapid extinctions in bighorn sheep. Conservation Biology 4: 91-98.

Bighorn Institute, 1997. Bighorn Institute -Year End Report to the California Department of Fish and Game, Sacramento.

Bleich, V. C., J.D. Wehausen, and S.A. Holl. 1990. Desert-dwelling mountain sheep: conservation implications of a naturally fragmented distribution. Conservation Biology 4: 383-390.

Bleich, V. C., R. T. Bowyer, A. M. Pauli, M. C. Nicholson, and R. W. Anthes. 1994. Mountain sheep Ovis canadensis and helicopter surveys: Ramifications for conservation of large mammals. Biological Conservation 70 : 1-7.

Bleich, V. C., J. D. Wehausen, R. R. Ramey II, and J. L. Rechel. 1996. Metapopulation theory and mountain sheep: implications for conservation. Pages 353-373 *in* Metapopulations and Wildlife Conservation. D.R. McCullough, ed. Island Press, Washington, D.C. 429pp.

Bleich, V.C., R. T. Bowyer, and J. D. Wehausen. 1997. Sexual segregation in mountain sheep: resources or predation? Wildlife Monographs. No. 134. The Wildlife Society. 50pp.

Blong, B. 1967. Desert bighorn and people in the Santa Rosa Mountains. The Wildlife Society Transactions. California-Nevada Section. Pages 66-70.

Blong, B. and W. Pollard. 1968. Summer water requirements of desert bighorn in the Santa Rosa Mtns., Calif., in 1965. California Fish and Game 54 : 289-296.

Boyce, W.M., P.W. Hedrick, N.E. Muggli-Cockett, S. Kalinowski, M.C.T. Penedo, and R. R. Ramey, II. 1997. Genetic variation of major histocompatibility complex and microsatellite loci: a comparison in bighorn sheep. Genetics 145: 421-433.

Boyce, W. M., R. R. Ramey II, T. C. Rodwell, E. S. Rubin, and R. S. Singer. 1999. Population subdivision among desert bighorn sheep (*Ovis canadensis)* ewes revealed by mitochondrial DNA analysis. Molecular Ecology 8: 99-106.

Bureau of Land Management. 1980. Santa Rosa Mountains Wildlife Habitat Management Plan: A Sikes Act Plan. Riverside District Office. 56 pp + app.

Campbell B. and R. Remington. 1981. Influence of construction activities on water-use patterns of desert sheep. Wildlife Society Bulletin 9: 63-65.

Cunningham, S. C. 1982. Aspects of the ecology of Peninsular desert bighorn sheep (Ovis canadensis cremnobates) in Carrizo Canyon, California. M. S. thesis. Arizona State University, Tempe. 76 pp.

Cunningham and J.C. deVos. 1992. Mortality of mountain sheep in the Black Canyon area of northwest Arizona. Desert Bighorn Council Transactions 36 : 27-29.

DeForge, J. R. 1972. Man's invasion into the bighorn's habitat. Desert Bighorn Council 16 :112-116.

Etchberger, R. C., P. R. Krausman, and R. Mazaika. 1989. Mountain sheep habitat characteristics in the Pusch Ridge Wilderness, Arizona. Journal of Wildlife Management 53 : 902-907.

Fairbanks, W. S., J. A. Bailey, and R. S. Cook. 1987. Habitat use by a low-elevation, semi-captive bighorn sheep population. Journal of Wildlife Management 51: 912-915.

Geist, V. 1971. Mountain sheep: a study in behavior and evolution. The University of Chicago Press. Chicago and London. 383 pp.

Guitierrez-Espeleta, G. A., S. T. Kalinowski, W. M. Boyce, and P. W. Hedrick. 1998. Genetic variation in desert bighorn sheep. Desert Bighorn Council Transactions 42: 1-10.

Goodson, N. J., D. R. Stevens, K. McCoy, J. Cole. 1999. Effects of river based recreation and livestock grazing on desert bighorn sheep on the Navajo Nation. Second North American Wild Sheep Conference April 6-9, 1999 Reno, NV.

Hamilton, K., S. A. Holl, C. L. Douglas. 1982. An evaluation of the effects of recreational activity on bighorn sheep in the San Gabriel Mountains, California. Desert Bighorn Council Transactions 26 : 50-55.

Hansen, C. G. 1980. The desert bighorn: its life history, ecology, and management *in* G. Monson and L. Sumner, eds. University of Arizona Press, Tucson. 370 pp.

Harris, L. K. 1992. Recreation in mountain sheep habitat. Ph. D. Dissertation. University of Arizona, Tucson. 156pp.

Hicks, L. L. and J. M. Elder. 1976. Human disturbance of Sierra Nevada bighorn sheep. Journal of Wildlife Management 43 : 909-915.

Holl, S. A. and V. C. Bleich. 1983. San Gabriel mountain sheep: biological and management considerations. USDA Forest Service San Bernadino National Forest. Administrative Report 136pp.

Horesji, B. L. 1976. Suckling and feeding behavior in relation to lamb survival in bighorn sheep (*Ovis canadensis canadensis* Shaw). Ph.D. Dissertation University of Calgary, Alberta. 265pp.

Jorgensen, P. 1974. Vehicle use at a desert bighorn watering site. Desert Bighorn Council Transactions 18 : 18-24.

Kelly, K. A. and P. R. Krausman. 2000.

King, M. M. and G. W. Workman. 1986. Response of desert bighorn sheep to human harassment: management implications. Transactions 51st North American Wildlife and Natural Reource Conference.

Krausman, P. R., W. C. Dunn, L. K. Harris, W. W. Shaw, and W. M. Boyce. 2000. Can mountain sheep and humans coexist? In prep.

Leslie, D. M., Jr., and C. L. Douglas. 1980. Human disturbance at water sources of desert bighorn sheep. Wildlife Society Bulletin 8 : 284-290.

Light, J. T., and R. Weaver. 1973. Report on bighorn sheep habitat study in the area for which an application was made to expand the Mt. Baldy winter sports facility. USDA Forest Service Cajon Ranger District, San Bernadino National Forest. 39 pp.

MacArthur, R.A., R.H. Johnston, and V. Geist. 1979. Factors influencing heart rate in free-ranging bighorn sheep: a physiological approach to the study of wildlife harassment. Canadian Journal of Zoology 57 : 2010 - 2021.

MacArthur, R. A. , V. Geist, and R. H. Johnston. 1982. Cardiac and behavioral responses of mountain sheep to human disturbance. Journal of Wildlife Management 46:351-358.

McCarthy, M. C. and J. A. Bailey. 1994. Habitat requirements of desert bighorn sheep. Special report No. 69. Colorado Division of Wildlife, Denver, CO.

McQuivey, R. P. 1978. The desert bighorn sheep of Nevada. Nevada Department of Fish and Game, Biological Bulletin No. 6. 81 pp.

Miller, M. E. 1999. Use of historical aerial photography to study vegetation change in the Negrito watershed, southwestern New Mexico. Southwestern Naturalist 44: 121-137.

Miller, G. D. and E. L. Smith. 1985. Human activity in desert bighorn habitat: what disturbs sheep? Desert Bighorn Council Transactions 1985 : 4-7.

Miller, R. F. and P. E. Wigand. 1994. Holocene changes in semiarid pinyon-juniper woodlands: Response to climate, fire, and human activities in the U.S. Great Basin. Bioscience 44: 465-476.

Oldemeyer, J. L., W. J. Barmore, and D. L. Gilbert. 1871. Winter ecology of bighorn sheep in Yellowstone National Park. Journal of Wildlife Management 35: 257-269.

Ough, W. D. and J. C. deVos. 1984. Intermountain travel corridors and their management implications for bighorn sheep. Desert Bighorn Council Transactions 28 : 32-36.

Papouchis, C. M., F. J. Singer, and W. Sloan. 2000. Effects of increasing recreational activity on desert bighorn sheep in Canyonlands National Park, Utah. Pages 364 - 391 *in* Singer, F. J. and M. A. Gudorf. Restoration of bighorn sheep metapopulations in and near 15 national parks: conservation of a severely fragmented species. USGS Open File Report 99-102, Midcontinent Ecological Science Center, Fort Collins, CO.

Purdy, K. G. and W. W. Shaw. 1981. An analysis of recreational use patterns in desert bighorn habitat: The Pusch Ridge Wilderness case. Desert Bighorn Council Transactions 25: 1-5.

Risenhoover, K. L. and J. A. Bailey. 1985. Foraging ecology of mountain sheep: implications for habitat management. Journal of Wildlife Management 49: 797-804.

Shannon, N.H., R. J. Hudson, V. C. Brink, and W. D. Kitts. 1975. Determinants of spatial distribution of Rocky Mountain bighorn sheep. Journal of Wildlife Management 39: 387-401.

U. S. Fish and Wildlife Service. 1992. Endangered and Threatened Wildlife and Plants: Proposed rule to list the Peninsular Ranges population of the desert bighorn sheep as endangered. Federal Register 57(90) : 19837 - 19843.

U.S. Fish and Wildife Service. 2000. Recovery plan for bighorn sheep in the Peninsular Ranges, California. U.S. Fish and Wildlife Service Portland, OR. xv + 251pp.

Van Dyke, W. A., A. Sands, J. Yoakum, A. Polenz, and J. Blaisdell. 1983. Wildlife habitats in managed rangelands - the Great Basin of southeastern Oregon: bighorn sheep. USDA Forest Service and USDI Bureau of Land Management General Technical Report PNW-159. 37pp.

Wagner, G. D. Wagner and J. M. Peek. Activity patterns of Rocky Mountain bighorn ewes in central Idaho. Second North American Wild Sheep Conference April 6-9, 1999 Reno, NV.

Wakelyn, L. A. 1987. Changing habitat conditions on bighorn sheep ranges in Colorado. Journal of Wildlife Management 51: 904-912.

Wehausen, J. D. 1980. Sierra Nevada bighorn sheep: history and population ecology. PhD dissertation. University of Michigan. 243 pp.